Advanced Communication Technology Satellite (ACTS) Multibeam Antenna On-Orbit Performance

Introduction

The NASA Lewis Research Center's Advanced Communication Technology Satellite (ACTS) was launched in September 1993. ACTS introduced several new technologies, including a multibeam antenna (MBA) operating at extremely short wavelengths never before used in communications. This antenna, which has both fixed and rapidly reconfigurable high-energy spot beams (150 miles in diameter), serves users equipped with small antenna terminals.

Extensive structural and thermal analyses have been performed for simulating the ACTS MBA on-orbit performance. The results show that the reflector surfaces (mainly the front subreflector), antenna support assembly, and metallic surfaces on the spacecraft body will be distorted because of the thermal effects of varying solar heating, which degrade the ACTS MBA performance.

Since ACTS was launched, a number of evaluations have been performed to assess MBA performance in the space environment. For example, the on-orbit performance measurements found systematic environmental disturbances to the MBA beam pointing. These disturbances were found to be imposed by the attitude control system, antenna and spacecraft mechanical alignments, and on-orbit thermal effects. As a result, the MBA may not always exactly cover the intended service area. In addition, the on-orbit measurements showed that antenna pointing accuracy is the performance parameter most sensitive to thermal distortions on the front subreflector surface and antenna support assemblies.

Several compensation approaches were tested and evaluated to restore on-orbit pointing stability. A combination of autotrack (75 percent of the time) and Earth sensor control (25 percent of the time) was found to be the best way to compensate for antenna pointing error during orbit. This approach greatly minimizes the effects of thermal distortions on antenna beam pointing.

Summary of Results

- Analysis and on-orbit measurements of the ACTS MBA performance indicated that thermal distortions are periodic. The table describes the system's effect with and without compensation for ground stations within a single spot beam.

ACTS MULTIBEAM ANTENNA RADIOFREQUENCY POINTING VARIATIONS

Type	Beam	Magnitude, deg	Axis	Duration	Operational effect

Rapidly varying	East	Less than 0.1	Roll	Less than 1 hr	Short-term effect marginal station. Use ESA control during event to minimize effect.
Diurnal variation	East and West	0.2	Pitch	12 hr/event	Significant signal variation can crash stations. Use biax drive to compensate.
Quasistatic	East and West	±0.4 ±0.2	Pitch Roll	14 days	Totally compensated by Autotrack.
Vibration	Transmit	±0.15	Pitch	1 Hz	Generally negligible.

- In future commercial communications satellites that use multibeam reflector systems at the Ka band (or that use gridded reflector structures and materials such as Aztroquartz (GE Astro, East Windsor, New Jersey) at higher frequencies), a sunshade should be employed to avoid large thermal distortions.

- The mechanical oscillations (nonthermal distortions) on the ACTS MBA are very difficult to compensate for. Future communications satellites should consider the mechanical oscillations a driver in their antenna mechanical design.

- The yaw control system can affect the beam pointing drastically, especially for those ground stations located away from either subsatellite longitude or autotrack boresight. Future spacecraft systems should take into account yaw estimation as a primary concern in their design goals.

- The ACTS MBA performance was found to be well within the expected range, and the transmit and receive beam optimization procedures were successfully executed. On-orbit MBA measurements have shown that all design limits have been met and that good pointing performance has been achieved.